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Meteorology requires global information today, uniformly distributed over the entire Earth, both with respect to the development of theory and from the standpoint of practical weather forecasting. Only spacecraft are in a position realistically to obtain such information. This also leads to a need to develop improved methods of observation from space. /8*

Thus, it is already possible to obtain a wide variety of information. Let us attempt to enumerate the basic types of such information: (1) Distribution of cloud cover over the globe; (2) Forms of circulation of a synoptic scale, as they are determined by the structure of cloud fields (atmospheric fronts, cyclonic vortices, zones of convergence and many others); (3) Dangerous situations such as tornadoes, tropical hurricanes, dust and sand storms, extensive zones of fog at sea and on the ocean, etc.; (4) Thermodynamic stability or instability in certain layers of the atmosphere, characterized by the shapes of the clouds, cloud convective components, and other characteristics; (5) The nature of the vertical movements in the atmosphere, detected on the basis of mesometeorological cloud structure;

* Numbers in the margin indicate pagination of original foreign text.

(6) The temperature and altitude of the upper limit of the clouds; (7) The results of sounding the structure of the atmosphere for the purpose of determining vertical and horizontal temperature distribution, atmospheric humidity, aerosol content, etc.; (8) Results of measurement of distribution of atmospheric components which are insignificant in volume but nonetheless important such as ozone, carbon dioxide, etc.; (9) Data on precise measurements of the components of the heat balance of the Earth as a planet; (10) The results of regular measurements of the so-called solar constant; (11) Results of investigations of the state of the sea surface (currents, waves, temperature, ice conditions); (12) Characteristics of the subjacent surface of the land, which is of interest from the meteorological standpoint (soil moisture, distribution of snow cover, temperature, etc.); (13) Estimating wind direction and possibly wind speed in different atmospheric strata. This list is incomplete.

Measurements from the satellites used at the present time /9
are processed by automatic devices according to a set program. It is only aboard manned spacecraft that more detailed nonstationary operations can be performed, thanks to the presence of the cosmonauts on board, who can consciously select the objects to be studied and correct the experimental program depending on the situation on Earth.

By way of explanation, let us examine one example from the area of weather forecasting. As we know, at the present time the development of macrocirculation processes is forecast by numerical methods by solving hydrodynamic equations. However, there is a gap between the prediction of the development of macrocirculation and the prediction of local weather, due to the fact that local weather is under the considerable influence of mesometeorological processes and depends upon the conditions of the landscape in general, including the effects of the subjacent surface. In this connection, future development of weather forecasting methods requires detailed information which will reflect the influence of both large and small-scale influences. It is particularly important in this connection to consider the vertical movements of the atmosphere, which cause the development or disappearance of the cloud cover, the development of trapping or inversion layers with accumulation of aerosol, etc. But the vertical points are not measured directly, and it is still unclear how measuring devices will be designed for this purpose. It is therefore necessary to find indirect methods of solving the problem. The best indicators of vertical movement are clouds, with their enormous diversity of shapes, reflecting the characteristics of the vertical movements in the atmosphere. How is the resolution of television pictures or photographs to be determined? It must be assumed that we will obtain details of cloud shapes just as clearly as we do with the naked eye from Earth, for example, at a distance of no more than a few kilometers, or as they appear from substratospheric altitudes. Such conditions will not be met by observations from meteorological satellites, but will be met by using photographs of cloud cover taken from orbiting stations.

Atmospheric mesoprocesses are not only large-scale phenomena which occur in atmospheric currents by virtue of the internal dynamics of the process or under the distorting influence of local conditions, but also consist of those phenomena which arise locally and independently of the influence of general transport. Examples of such local phenomena would be mountain-valley circulation, convective cloud cover or fogs, the breeze effect and many others. We can only understand the origin of strictly local phenomena on the basis of very detailed information.

It is completely natural that individual episodic observations are valuable for carrying out research efforts, for working out methods of using data and for improving the methods of observations themselves. This type of data has already been obtained in part from manned spacecraft in the "Soyuz" series.

Work on the systematic study of atmospheric phenomena from aboard manned orbital stations was begun by the crew of the first station of this kind, the "Salyut-1", Pilot-Cosmonauts G. M. Dobrovol'skiy, V. M. Volkov and V. I. Patsayev [3].

The scientific experiments performed aboard the orbital station included observations of atmospheric phenomena, cloud cover and the cloudless surfaces of the oceans and seas.

In particular, these observations included visual surveys of the Earth and the space near the Earth. Cameras photographed striking or unusual phenomena.

There is particular interest in the area of the planet which is occupied by the ocean. The water in the oceans covers more than two-thirds of the area of the globe, and the network of meteorological stations there is especially sparse. Much of what takes place in the atmosphere over the ocean as well as its /10 interaction with the ocean is still unknown as far as man is concerned.

On what did the cosmonauts concentrate their attention?

First of all, tropical cyclones, which arise in the areas of the ocean near the Equator and pose a serious danger to mankind. Cloud systems associated with these cyclones can be seen from space as giant cloud vortices with diameters of hundreds of kilometers.

Another important problem was observing the actual surfaces of the oceans and the clouds which form above them. Observing the surface of the ocean, a cosmonaut can distinguish inhomogeneities in the color of the water, associated with ocean currents, emergence of water from great depths, and emptying of large rivers into the oceans. Following the cloud cover, the cosmonaut can distinguish various patterns in it whose shape is associated with a given type of movement of the atmospheric air over the surface of the ocean.

Observations aboard the spacecraft were carried out according to a previously developed method which incorporated all of the experience gained in observations during previous flights aboard manned spacecraft in the "Voskhod" and "Soyuz" series. The cosmonauts were acquainted in great detail with the method of observation during their period of preflight training. Aboard the spacecraft, the crew were given test sheets of characteristic types of cloud cover, reflecting certain atmospheric processes.

In addition to the independent work of the cosmonauts, the latter hold consultations with the Space Flight Control Center concerning the distribution of tropical storms detected earlier, and about areas where they might possibly develop. In addition, the cosmonauts receive advice on regions where interesting cloud formations might be observed, as well as other atmospheric phenomena in the extratropical and tropical latitudes of the Southern and Northern Hemispheres.

The crew of the "Salyut-1" detected and photographed many interesting cloud situations inaccessible to aircraft observations and indistinguishable in pictures taken from automatic satellites. We will present several examples of such situations.

Let us examine the series of vertical aerial photographs made on 14 June 1971 over the Altay (Photo I). From the standpoint of large-scale synoptic processes, on this particular day above the Altay there was a remote tail of a cyclone, characterized by convective clouds.

The photographs exhibit a high level of resolution. One can clearly see even individual small cumulus clouds, not to mention the highly developed cumulus clouds and cloud accumulations. In many places, the photographs clearly show mountain ridges, covered by eternal snow. One can easily see the snow line. In addition, mountain valleys and the rivers flowing along them, together with their tributaries, are visible.

The photograph was taken at approximately 0900 local mean solar time and required less than one minute's exposure. From the standpoint of development of a given cloud cover, this series of photographs covering a strip about 500 kilometers long may be considered practically instantaneous.

In looking at the photographs, one is struck first of all by the fact that the clouds of the convective type do not form only in the morning hours, since many large accumulations of convective clouds and even individual clouds are already five to seven kilometers in cross section. The dimensions of these accumulations and individual clouds increase with transition from one picture to another as we move from west to east, while the eastern pictures show high cirrus clouds above the cumulus clouds (Photo 1, at the right). This is all quite understandable if we take into account that the eastern photographs are located closer to the internal part of the cyclone. Consequently, we must conclude that this type of cloud cover was largely retained from the previous day. This is also indicated by the meridional direction of the chain of cumulus clouds; the chains can be seen most clearly in the /10 western pictures (Photo 1, left) and they are oriented across the air flow in the troposphere above the mountains.

However, in a stereoscopic analysis of these photographs we can detect the occurrence of cumulus clouds which begin as a result of thermal convection on a particular day. These clouds seem less dense; they are small in size and appear along the mountain slopes. Under the stereoscope the clouds can be seen clearly even above a snow-covered surface (if the wind has blown them there).

What important mesometeorological characteristics are revealed by photographs taken from a spacecraft?

First of all, we must keep in mind that all large valleys and ravines are free of clouds. This can be explained by the existence of the night wind, blowing down along the valley and causing the air to settle in the valley. The cloudless valleys make it possible to orient oneself easily in the orography of the region.

Secondly, morning convection arises along the slopes of the mountains, along the side of the valley which is lit by the Sun. The clouds which form do not collect on the ridge itself, but remain on one side or the other. This can be seen clearly in Photo 1, at the right. In this case, when the ridge was covered with snow, the cumulus clouds did not form above such a cold subjacent surface. In addition, there was a steady wind here for a long time as the night drew to a close.

In the third place, one can see with unusual clarity the snow line in the mountains, with all of its details. The texture of the snow-covered ridges showed up clearly in the photographs against the texture of the cloud cover. However, in those situations when old snow was covered with newly fallen snow, the texture changed and became uniformly smooth.

An examination of the photograph shown in Photo 1 will illustrate examples in which the influence of the landscape and of the local circulation of the air caused by it on the structure of the cloud cover is reflected.

Another long series of photographs made by the cosmonauts belongs to the category of photos in which large-scale atmospheric circulation was reflected. This paper shows several of these photos. They show the cloud systems of cyclones that developed in the various parts of the globe.

On 11 June 1971 the central part of a large occluded cyclone was photographed above the Far East. This was a high baric formation; the cyclonic circulation occupied the entire troposphere, and there were no large horizontal thermal gradients in the cyclone. The cloud system of this extensive cyclone constituted a giant cloud vortex measuring about 2000 kilometers across. The crew of the manned spacecraft photographed the eye of this cloud vortex (Photo 2).

In tone and structure, the appearance of the cloud cover in the pictures clearly shows the characteristics of air circulation in the eye of the cyclone. One can clearly see the vortical structure: the spiral cloud bands converge at point A, which is the center of the vortex. It would appear that the eye of this old cyclone would have to contain cumulus and stratocumulus clouds, with the upper limit at a not very great altitude [2]. Such clouds can in fact be seen in the western and southern parts of the eye of the vortex. These are dense, bright clouds, between which large gaps can be seen. The clouds form banks and bands, converging at point A, while convective cells can be seen in the west. Not all of these forms can be distinguished by their geometric structure, and the relief of the terrain has a distorting influence. Above, the clouds are covered by a thin transparent shroud of cirrus clouds, which constitutes the remainder of the eroded cloud system from the occlusion. / 12

This cycline is distinguished from similar ones by the dense cloud band CCC, about 80 kilometers wide and 500 kilometers long. It is located to the north of the cloud vortex and is composed of a compact, dense, stratified cloud cover. The northern edge of this band is sharply delimited by a narrow, dark band which constitutes the shadow thrown by the high cirrostratus clouds of which the cloud band is composed on the lower clouds of the cumulus and stratocomulus variety. This cloud band attracted our attention in particular. It was found to be associated with the rise of relatively warm air with a strong easterly flow. On the basis of the data of atmospheric wind soundings, the flow rate here reached 120 kilometers per hour. This was a mesoscalar structural flow; its width did not exceed 100 kilometers, and its length was 500 kilometers. Hence, the dimensions of the cloud band were commensurate with the dimensions of this miniature flow. This characteristic of the cloud band along the valley can be clearly seen to be reflected in the flow of strong winds; to the east of the band of dense cloud cover, it was interrupted at places where the velocity of the eastern flow increased sharply and in the west at places where it sharply dropped off. This particular case illustrates the possibility of using detailed photographs to determine the nature of the complex and slightly unusual structure of occluded cyclones.

Let us examine two more characteristic pictures of the cloud systems of cyclones (Photos 3 and 4). They were both obtained on 27 June over the southern part of the aquatorium of the Indian Ocean. Each of these pictures shows a cyclonic vortex. They are representatives of winter cyclones in the middle latitudes of the Southern Hemisphere. At this time of year cyclones usually move rapidly (about 50-60 km/hr) from west to east along the altitude frontal zone, which surrounds the Antartic at approximately 50° F in a nearly continuous belt.

Photo 3 also shows a younger cyclone. One can clearly see the colder part to the south and the warmer sector in the north. The cloud vortex has already formed and occlusion of the cyclone has begun.

There are cumulus and stratocumulus clouds DD in the cold air of the cloud. Their thickness is not very great, and is determined by the comparatively low moisture content of the air flowing from the Antarctic coast. In the warm sector of the cyclone E, there is not much cloud cover but it is more vertically developed. Here, above the surface of the water, cumulus and cumulonimbus clouds develop, whose tops reach the ice nuclei level. This is indicated by their blurred appearance.

Figure 4 is also a cyclone which is already no longer young. The cloud system in it is well developed. The occlusion process has already peaked and one can see separation of the cloud vortex from the basic mass of frontal zone clouds.

The cases discussed here show the considerable diversity of the cloud picture and the complexity of air circulation within the cyclone, especially in its eye which was mentioned previously [1].

We have discussed here the possibility of studying from a manned orbital station only one of the problems discussed at the start of this section. The range of problems within the scope of atmospheric study and the means of observation aboard manned stations will naturally expand and improve.

It is difficult to overestimate the practical aspects of such work.

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